

Combining microwave and other complementary satellite data with land model outputs to advance in the estimation of global land surface heat fluxes

Carlos Jimenez¹, Catherine Prigent¹, Filipe Aires²

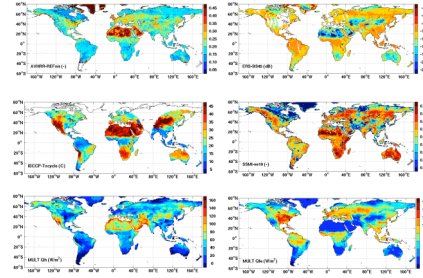
¹ CNRS/LERMA, Observatoire de Paris, Paris, France ² CNRS/IPSL/LMD, University Paris VI, Paris, France

INTRODUCTION

Land surface heat fluxes are essential components of the water and energy cycles. Despite a large body of work, there is no systematic data analysis activity underway to produce a complete, physically consistent, global, multi-decadal land heat flux data product. The GEWEX Radiation Panel (GRP) recently launched an activity, called LandFlux [1], to develop the needed capabilities to derive such data product. In this context, we have started to study the sensitivity of a suite of satellite observations to land surface heat fluxes and to investigate the possibility of estimating the fluxes from the satellite measurements [2].

FLUXES and satellite OBSERVATIONS

Fig 1. Examples of satellite data and heat fluxes for June 93. The satellite data includes VIS and near-IR reflectances (AVHRR), thermal IR surface skin temperature and its diurnal cycle (ISCCP), active microwave backscatter (ERS scatterometer), and passive microwave emissivity (SSM/I). Fluxes at a global scale are adopted from land surface models: the GSWP-2 multi-model analysis and the ISBA and ORCHIDEE participating models, along with the NCEP/NCAR reanalysis. All data were placed on a 0.25°x0.25° grid and monthly averaged (1993-1995).



METHODOLOGY



Fig 2. Phases of the proposed methodology. In the calibration phase, a statistical model (SM) for each considered land surface model (LSM) is calibrated with the satellite data and original land fluxes (using Feb-May-Aug-Nov 93). In the estimation phase, the SMs produce the estimated fluxes from the satellite data (remaining months in 93-95). In the evaluation phase the original fluxes produced by the LSMs and the estimated fluxes produced by the SMs are compared to evaluate the consistency between both flux datasets. The SM is based on a neural network scheme.

Satellite data INFORMATION CONTENT

Satellite products	Correlation		RMS	
	GSWP	NCEP	GSWP	NCEP
Sensible flux				
Emissivity	0.44	0.61	27.1(58.1)	34.9(63.0)
Backscatter	0.32	0.52	28.6(61.3)	37.5(67.7)
Reflectance	0.42	0.59	27.4(58.8)	35.4(63.8)
Skin Temperature	0.64	0.63	23.0(49.5)	34.1(61.6)
Diurnal Cycle	0.59	0.71	24.4(52.3)	30.8(55.5)
Net Radiation	0.69	0.70	21.8(46.8)	31.5(56.9)
All	0.83	0.84	16.7(36.0)	23.5(42.4)
Latent flux				
Emissivity	0.80	0.83	21.6(46.2)	31.5(56.9)
Backscatter	0.70	0.75	25.6(55.0)	36.7(66.2)
Reflectance	0.82	0.79	20.2(43.4)	34.5(62.4)
Skin Temperature	0.48	0.48	31.5(67.7)	49.3(89.1)
Diurnal Cycle	0.72	0.76	24.9(53.4)	36.2(65.3)
Net Radiation	0.82	0.84	20.6(44.3)	29.5(53.4)
All	0.92	0.92	14.2(30.5)	22.0(39.7)

Table 1. Correlation coefficients and RMS errors for a non-linear estimation between the individual satellite-derived variables (SSM/I emissivity, ERS backscatter, AVHRR reflectance, and ISCCP skin temperature, amplitude of its diurnal cycle and net radiation) and the sensible and latent fluxes (GSWP multi-model analysis and NCEP reanalysis). Correlation and errors are also given when all satellite variables are simultaneously used in the estimation (All). The RMS errors are given in W/m² and as a percentage of the mean flux (in brackets).

Estimation ERROR

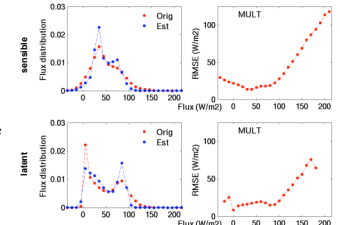


Fig 3. Summary of statistics for the 93-95 GSWP multi-model original (Orig) and estimated (Est) heat fluxes. The density distribution of original (red) and estimated (blue) fluxes (normalized to unity area) are plotted in the left figures, the distributions of the RMS estimation error are plotted in the right figures. The top panel shows the sensible fluxes, the bottom panel the latent fluxes.

Comparing GEOGRAPHICAL and TEMPORAL patterns

Fig 4. Aug 95 GSWP multi-model original (left) and estimated (right) sensible (top) and latent (bottom) fluxes. The maps show that the estimated fluxes capture well the regional variations associated to different climate and vegetation regimes, although some exceptions are visible.

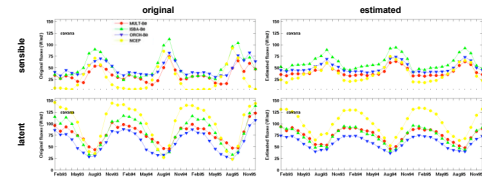
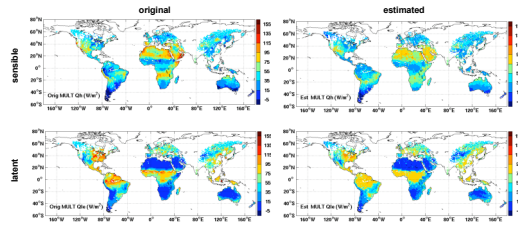


Fig 5. Original (left) and estimated (right) zonally averaged sensible (top) and latent (bottom) fluxes for savanna areas. The exercise was also carried out for tropical, conifers, steppes, mountains and deserts. In general, temporal patterns are well captured in the estimated fluxes.

Detecting LOCAL flux anomalies

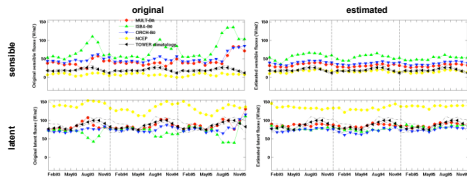


Fig 6. Original (left) and estimated (right) averaged sensible (top) and latent (bottom) fluxes in a 2°x2° box around the Tapajós Forest (Brazil). An annual climatology from tower fluxes is also plotted. The statistical model (SM) cannot remove existing biases at global scale. But for specific regions where there is a departure from the global relationship, the SM can locally remove biases and produce fluxes more consistent with the learned global relationships. The anomalous fluxes at the end of 95 (related to a GSWP radiation forcing anomaly) and the questionable ISBA flux partitioning are removed by the SM driven by the satellite data.

Comparing with IN-SITU fluxes

Table 2. Comparison of the fluxes from the GSWP multi-model, ISBA, ORCHIDEE, and NCEP models with tower fluxes (2000-2006 annual climatologies for 76 AmeriFlux stations). LSM refers to the original model fluxes, SM to the fluxes estimated by each corresponding statistical model. The correlation between model and tower fluxes is given, together with the RMS of the differences between model and tower fluxes, expressed as percentage of the tower fluxes. Similar statistics are obtained for the original and the estimated fluxes. But note that this exercise is essentially limited to mid-latitude areas and cannot be conclusive in the context of a global comparison.

	Correlation		RMSE(%)	
	LSM	SM	LSM	SM
Sensible flux				
MULT	0.66	0.68	66.3	59.1
ISBA	0.64	0.68	78.5	68.0
ORCH	0.70	0.67	51.8	52.8
NCEP	0.73	0.67	66.7	58.5
Latent flux				
MULT	0.77	0.78	56.8	46.9
ISBA	0.70	0.71	58.0	55.0
ORCH	0.82	0.79	40.4	47.8
NCEP	0.76	0.75	72.0	64.4

CONCLUSIONS

This methodology is tightly related to land surface model outputs and cannot be considered as a method to derive independent land surface turbulent fluxes from satellite observations. Nevertheless this statistical analysis can be an efficient tool to diagnose modelling difficulties or to combine satellite data and land models to produce global fluxes maximizing their relational consistency, and in this sense, a pragmatic step forward in the search for methodologies to produce a global multi-decadal heat flux climatology product.

REFERENCES

- [1] More information online at http://grp.giss.nasa.gov/landflux_1st-workshop.html
- [2] More information at <http://aramis.obspm.fr/~jimenez/>

ACKNOWLEDGMENTS

All satellite, models and tower flux science teams are acknowledged for kindly providing all the data used in this work.